Overcoming inertia: insights from evolutionary economics into improved energy and climate policy

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Overcoming inertia: insights from evolutionary economics into improved energy and climate policies

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The 'efficiency paradox' has generated controversy and suggests that mainstream economics is not neutral in the way it deals with climate change. An alternative economic framework, evolutionary economics, is used to investigate this crucial issue and offer insights into the development of a complementary framework for designing climate policy and for managing the transition to a low-carbon society. The evolutionary framework allows us to identify the presence of two sources of inertia (i.e. at the individual level through 'habits' and at the level of socio-technical systems) that mutually reinforce each other in a path-dependent manner. To overcome 'carbon lock-in', decision-makers should design measures (e.g. commitment strategies, niche management) that specifically target those change-resisting factors, as they tend to reduce the efficiency of traditional instruments. A series of recommendations for policy-makers is provided.

Keywords: climate change; energy consumption; evolutionary economics; habits; technological lock-in; transitions

Le « paradoxe d'efficience » en énergie, qui a suscité de nombreux débats, suggère que la science économique dominante n'est pas neutre dans sa manière d'aborder le problème des changements climatiques. Cette question essentielle est ici étudiée à l'aide d'un autre cadre d'analyse, celui de l'économie évolutionniste. L'objectif est de fournir des éléments visant à développer une approche complémentaire pour l'élaboration des politiques climatiques et la gestion de la transition vers une société sobre en carbone. L'approche évolutionniste nous permet de décrire la présence de deux sources d'inertie (c'est-à-dire au niveau individuel, celui des « habitudes », et au niveau des systèmes sociotechniques) qui se renforcent mutuellement tout en étant fortement dépendantes de la trajectoire initialement suivie. Pour surmonter le «verrouillage carbone», les décideurs devraient donc concevoir des mesures (ex : stratégies d'engagement, gestion de niche) ciblant spécifiquement ces facteurs de résistance au changement étant donné leur impact négatif sur l'efficacité des instruments traditionnels. A cet égard, plusieurs recommandations sont proposées à destination des décideurs.

Mots clés: changement climatique; consommation d'énergie; économie évolutionniste; habitudes; transitions; verrouillage technologique

1. Introduction

From the very beginning of international talks on climate change, up until the most recent discussions on a post-Kyoto international framework, economic arguments have turned out to be crucial elements of the analysis that shapes policy responses to the climate threat (Maréchal, 2007). This can be illustrated by the prominent role that economics has played in the different analyses produced by the Intergovernmental Panel on Climate Change (IPCC) to assess the impact of climate change on society (Toman, 2006).

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As mentioned by Gowdy (2004), the mainstream paradigm is the dominant standard among economists and their audience.[1] It thus provides the theoretical background on which policy-making is based. Climate policy is no exception, as the mainstream view in economics has been a key factor in designing climate policies (Toman, 2006). This is illustrated by the fact that strict Walrasian computable general equilibrium (CGE) models – the primary tool of mainstream economics – have clearly dominated most of climate-related economic analysis (Laitner et al., 2000; Löschel, 2002).[2] However, the use of such models is being questioned. As mentioned by Nannen and van den Bergh (2008, p. 1), '[a]lthough these models have generated many clear insights, they do not represent the full range of model approaches and questions that can be addressed'. For instance, the fact that the mainstream approach is qualified as being ahistorical (Foster, 1997, p. 432) means that crucial elements such as the path-dependence of technological change cannot be grasped.

Accordingly, the purpose of this article is to investigate how the analytical framework of evolutionary economics could provide an insightful complement for dealing with the climate issue. The choice of an evolutionary line of thought is quite straightforward: given its focus on innovation and system change, it provides a useful approach to start with for assessing and managing the necessary transition towards a low-carbon economy.

This article brings together and develops further the insights relating to the notion of 'lock-in' that arise from the evolutionary perspective. These insights have been exposed separately in two earlier works that were focused on energy issues (Maréchal, 2007, 2009). Building on the view that individuals and institutions mutually constitute each other, the aim of this article is to provide a framework that allows for both the socio-technical and the behavioural sides of the lock-in process to be depicted and accounted for in the analysis. Beyond relating this analytical perspective to ongoing theoretical and policy debates on climate change, this article also provides novel insights in terms of policy recommendations that target both sources of inertia and also their interplay in order to find ways to overcome what has been termed the 'carbon lock-in' (Unruh, 2000).

The article is structured as follows. In the following section, we first present a brief overview of the main assumptions endorsed in traditional economic analyses of environmental issues. The rest of Section 2 is devoted to the implications of relying on the framework of mainstream economics for dealing with climate change, by looking more closely at the debate on the 'efficiency paradox'. Section 3 discusses the complementary insights that arise from adopting an evolutionary approach, highlighting the path-dependence and lock-in of both consumption behaviours and technological change. In Section 4, we deal with the implications of our approach for policy-making in the field of energy and climate change. Section 5 then concludes.

2. Climate policy analyses and their limits

2.1. Core economic assumptions and the climate change context

The way in which economists usually frame the decision-making process is to assume that agents are perfectly rational (or behave as if they were so). It thus follows that the policy recommendations of most economists are 'conforming to the axioms of consumer choice embodied in *Homo economicus*' (Gowdy, 2007, p. 650). Echoing the work of Herbert Simon on 'bounded rationality',[3] this is sometimes viewed as 'the 'unbounded rationality' assumption of mainstream economics' (Venkatchalam, 2008, p. 640). Beyond the obvious limited availability of information (and of the time to process it), what is crucially missing in the rational actor framework with respect to knowledge is its potential ambiguity as well as differences in interpretation and its inherently tacit nature. All these aspects are essential for understanding the determinants of consumer behaviour and, most specifically, the role played by habits. As shown in Section 3, this dimension is of importance for energy- and climate-related analyses.

Although the underlying assumptions of the rational model have been called into question for quite a long time (Allais, 1953; Tversky and Kahneman, 1974), it is only with recent developments in cognitive science and related work in behavioural economics and neuroeconomics (see, for instance, Camerer et al., 2005), that these criticisms have begun to have an impact. This is largely due to the experimental nature of these recent developments, which made them replicable and thus amenable to testing (Gintis, 2007). What is also important in this respect is that the abundant empirical evidence gathered leads to the identification of some regularities of behaviour that allow for an alternative model to be envisaged (Gowdy, 2008). These regularities change the way usual notions – such as self-interest and preferences – are to be understood, since they now have to account for crucial elements such as strong reciprocity, loss aversion, hyperbolic discounting, habituation, etc. (Gowdy, 2007, 2008).

Nevertheless, the traditional paradigm remains the dominant standard among economists. Policy advice is thus 'based on these outdated representations of human behaviour and commodity production' (Gowdy and Erickson, 2005, p. 208). This is also the case of all the different streams of normative environmental economics such as the Pigouvian approach of negative externality, the Coasian property rights approach, or the commonly used cost–benefit analysis (Venkatchalam, 2008, p. 640). But, as recently acknowledged by Dasgupta (2008, p. 46) 'property rights to natural capital are often either vaguely defined or weakly enforced, meaning that nature's services are underpriced in the market'.

Economists working on climate change should thus broaden what they consider to be the task at hand. This means going beyond the idea of simply assigning property rights and adjusting relative prices in order to avoid negative externalities induced by economic growth. Although it may be deemed to be a departure from the traditional treatment of climate change by economists (Barker, 2008, p. 175), the Stern Review (Stern, 2006) is still based on rational choice theory (i.e. under the form of the related 'expected utility theory').[4] It has also been designed in this spirit of making predictions about the negative impacts of economic growth and measuring them. However, beyond the debate around the Stern Review, a growing part of the scientific community is now becoming more inclined to frame the problem differently (Dasgupta, 2007).

Indeed, the way of framing climate change using only quantitative and formal economic analysis led economists to press for what Dasgupta (2007, p. 23) qualifies as a 'misplaced concreteness'.[5] This is largely due to the particular characteristics of the climate threat, which cannot easily be dealt with using the usual economic tools. For instance, since the view that 'economic processes tend towards timeless equilibrium states remains the foundation upon which mainstream economic analysis is built' (Foster, 1997, p. 429), this leaves room for analyses to be performed considering economic evolution as a reversible process. This is obviously in contradiction to the potential irreversibility of some predicted impacts of climate change. The issue at stake is thus one of adequately dealing with events characterized by low probability of occurrence and high potential impact. This problem that arises from 'the incredible magnitude of the deep structural uncertainties that are involved in climate-change analysis' is acknowledged in Weitzman (2009, p. 35), where it is claimed to make conventional cost–benefit analyses 'especially and unusually misleading'.

The 'efficiency paradox' provides an insightful illustration of the need for economists to widen their usual approach which, as will be shown, can also be considered to have been partly misleading.

2.2. The 'efficiency paradox'

A great deal of research reported in the climate-related literature has been devoted to analysing what has been termed the 'no-regret' emission reduction potential, which triggered an extensive debate among economists.[6] An emission reduction potential is said to be 'no-regret' when the costs of implementing a measure are more than offset by the benefits it generates, such as reduced energy bills (Maréchal, 2007). Still, even though they are highly profitable, most energy-efficient investments are not implemented spontaneously by economic agents, which leads to what has been termed the 'efficiency gap' (see Jaffe and Stavins, 1994; Krause, 1996) or the 'efficiency paradox' (DeCanio, 1998).

As shown in more detail by Maréchal (2009), the use of the mainstream framework of analysis has clearly been misleading with respect to this important debate.[7] To begin with, it is important to recall that the 'efficiency paradox' was first highlighted by bottom-up engineering approaches (i.e. those that do not rely on the standard framework of *Homo economicus*). As mentioned by DeCanio (1998), it is the incompatibility of this 'efficiency paradox' with mainstream theory that explains the initial scepticism of economists regarding the existence of such untapped profitable opportunities. Indeed, according to the mainstream paradigm, if such a profitable potential did exist, 'unboundedly rational' economic agents would eventually undertake the necessary investments to capture it (Sutherland, 2000).

After having argued against the existence of a 'no-regret' potential at the beginning, mainstream economists, faced with overwhelming evidence on the 'efficiency gap', resorted to the traditional view of 'market failures' that lead to erroneous market signals to rescue the *Homo economicus* paradigm.[8] Based on this kind of framework, the goal is then to provide economic agents with the correct information to persuade them to invest in energy-efficient measures.

Again, empirical studies have shown that the picture is not as simple. First, bottom-up studies have shown that transaction costs, although they exist, do not quite offset the benefits from identified profitable energy-efficient investments (see Brown, 2001, for a survey of such studies). Second, and more fundamentally, empirical studies have shown that there were other obstacles to profitable energy-efficient investments that are of a different nature than economic market failures.[9] Non-economic obstacles – which have mostly been neglected by energy economists – are thus an important part of the explanation that requires to be appropriately understood. They are often referred to as 'barriers' and partly relate to the aforementioned 'bounded rationality' of economic agents.[10] As shown in the following section, the stance of this article is that the framework of evolutionary economics is very useful in that it is able to provide a two-fold account (i.e. relying on both individual and socio-technical sources of inertia) of this limited rationality of individuals – which refers to their incapacity of acting purely as optimizing agents.

3. An evolutionary approach to climate policy: path-dependence

More than a century ago, Thorstein Veblen was already wondering 'why economics is not an evolutionary science' (Veblen, 1898). His work is still very insightful for those currently involved in climate policy, as he can be viewed as the precursor of the notions both of path-dependence and of habits. In turn, those two notions provide a response to the drawbacks raised in Section 2. On the one hand, the evolutionary approach of habits can serve to explain the efficiency paradox. On the other hand, the notion of path-dependence provides an interesting starting point on which to build alternative policies and measures aimed at inducing the needed technological changes towards a low-carbon economy.

3.1. The evolutionary framework and environmental issues

Veblen's legacy is significant when it comes to thinking about institutions, evolution and change. Not only has Veblen depicted the institutional foundation on which capitalism is built but he also suggested a way for better grasping the interactions between individuals and social forces – especially with the notion of habits for both firms and consumers. It is to be noted that Veblen's main concerns were not about environmental issues as such, but rather about the concept of evolution and the way in which economists misused analogy for observing economic change. It was not until several decades later, with the pioneer work of Boulding (1981) and Georgescu-Roegen (1971), that a formal connection between the environmental and evolutionary agendas was eventually made (for a survey, see van den Bergh, 2007; Witt 2008). However, despite their great insights, these works remained largely ignored within the field of evolutionary economics until recently (Dosi and Grazzi, 2006; Witt, 2008).

The most accomplished work within the field of evolutionary economics is undoubtedly the seminal book of Nelson and Winter (1982), which explicitly presents a theoretical framework for thinking about evolution and change (Arena and Lazaric, 2003). Their source of inspiration comes from Joseph Schumpeter and Herbert Simon, from whom they inherited this dynamic and innovative way of thinking about changes. Their main achievement is to provide a more realistic vision of the firm. Relying strongly on the aforementioned idea of bounded rationality, the firm is no longer seen as being driven only by the primary goal of profit maximization but also by its survival given the environment in which it operates.

In such a framework, innovation matters for a firm's growth and development, but 'satisfying' (i.e. not necessarily optimizing) strategies such as organizational routines also play a significant role (Becker et al., 2005). Routines are not only the knowledge base of the firm but also its organizational memory, that is to say the locus where knowledge is selected, stored and activated (Lazaric and Denis, 2005). Skills used by employees, organizational routines and innovations are the necessary triptych for ensuring a firm's viability in a long-term perspective. It follows that what is important here is not so much to have 'good' innovations but to rely on satisfactory routines for fully benefiting from innovative activity. Organizational inertia then becomes a major concern, since it is seen as a way of protecting firms from turbulence. Learning and adaptation are certainly the most satisfactory strategies for running a business in contexts fraught with uncertainty and unpredictability (Nelson, 2008). Putting the emphasis on bounded rationality is not only valid for groups such as organizations or firms, but also for individuals. Whereas firms have organizational routines, the satisfactory strategies of individuals are commonly called habits.[11]

Recently, some evolutionary models have started to deal more explicitly with environmental issues through a reconciliation of Veblen's insights with the framework developed by Nelson and Winter (for a survey of such models, see Faber and Frenken, 2008). The added value of the evolutionary framework in economics with respect to environmental policy is that it highlights the role played by inertia and path-dependence at the level of firms, consumers and technologies.[12] Taken together, this tends to favour the 'lock-in' of socio-technical systems, as shown in the rest of this section. As paradoxical as it may seem, it is essential to have a good understanding of the underlying causes of inertia prior to deciding how to enforce a change. Given that routines and habits 'are performed by people who think and feel and care', they also offer 'a tremendous potential for change' (Feldman, 2000, p. 614).

3.2. Path-dependence of economic change: the problem of technological lock-in

Given the need to shift to a low-carbon economy, as well as the unsatisfactory treatment of technological change in mainstream modelling (Maréchal, 2007; Nannen and van den Bergh, 2008), turning to the framework of evolutionary economics appears promising, considering its core characteristics.

Building on earlier work (Maréchal, 2007), defining what can be considered an evolutionary view of technological change (TC) may be done by starting from two elements. The first is the lack of formal historical connection which is identified as a major drawback of many analyses (Foster, 1997, p. 433). This inevitably leads towards what could be called the 'David and Arthur theory' of path-dependence and lock-in, which stresses the historically contingent nature of economic change (see David, 1985; Arthur, 1989).

The second element is that the added value of an evolutionary approach of TC, even compared with the most recent analyses based on endogenous modelling of TC, is that TC is 'contextualized' (Mulder et al., 1999). To be more precise, this means that the circumstances of its emergence are explained – which is highlighted through a systemic vision of technologies as 'interrelated' (see Veblen, 1915, p. 130).

It is important to note that modelling has gone through major improvements recently, especially in the field of climate policy, where models with endogenous technical change (ETC) have been developed (see Edenhofer et al., 2006). However, even though these models incorporate a form of learning processes with increasing returns, they still fail to integrate the main features of the evolutionary-inspired approach of TC, namely systemic interdependencies, heterogeneity of agents, and historical contingencies (Maréchal, 2007, p. 5186).

To briefly illustrate what results from taking into account both the contextualization and the historical contingencies, it is again enlightening to turn to Thorstein Veblen. Using the example of British small wagons, Veblen (1915) shows that systemic interdependencies imply that technologies can no longer be seen as isolated but rather as belonging to technological systems. Those systems can be defined as 'interrelated components connected in a network or infrastructure that includes physical, social and informational elements' (Unruh, 2000, p. 819). Adding the fact that technologies are also dependent upon and connected with the wider range of cultural, organizational and institutional aspects of their environment that enable them to work together, we end up with what Geels and Kemp (2007) call socio-technical systems (STS)[13] or what Unruh (2000) calls techno-institutional complexes (TIC).

This intertwining of different elements that characterizes a STS sheds light on the potential inertia of such systems. Indeed, once historical conditions have led to the emergence of a STS, their multiple components contribute to stabilize the system in a self-reinforcing manner. The nature and type of a STS is thus dependent upon the path followed[14] and is further perpetuated through the interactions of its multiple elements. Positive feedbacks (i.e. increasing returns to adoption) act as a sort of snowball which results in the locking-in of the incumbent STS following a path-dependent process.

3.3. 'Path-dependence' of consumption behaviours: the role of habits

Even though the idea of 'habituation' was explicitly mentioned in the pioneer work of Paul David, the 'behavioural' part has been somewhat overlooked in the literature that followed on the lock-in process (Barnes et al., 2004, p. 372). However, through focusing almost exclusively on the 'technological' side, an important part of the explanation for the locking-in of the carbon-based STS is missing. As described below, the role of habits (i.e. behavioural predispositions to repeat a well-practised action that is triggered by a contextual cue)[15] is essential for explaining the 'efficiency paradox'.

'Most of the time what we do is what we do most of the time' (Townsend and Bever, 2001, p. 2). This often-quoted sentence is meant to emphasize that much of our behaviour in daily life is characterized by repetition. From the empirical work of Wendy Wood and colleagues (Wood et al., 2002; Quinn and Wood, 2005), we know that many activities are not only repetitive in frequency but they also are performed in stable contexts. Such consistency sets a favourable breeding ground for habits (i.e. the behavioural predisposition to repeat a well-practised action given a context) to develop (Ouellette and Wood, 1998). Once formed in those circumstances of both high frequency and stability, habits then become a strong predictor of behaviour 'over and above intentions, suggesting that such behaviour is initiated without much deliberation and thought' (Danner et al., 2008, p. 246). The obvious advantage of adopting this kind of 'habit' in decision-making is that it frees up resources than can be devoted to solving non-routine problems.

The concept of habits is essential in analysing the determinants of domestic energy consumption, as it sheds an insightful light on the puzzling question of why it keeps rising even though there is an evident increase in awareness and concern about energy-related environmental issues such as climate change. Indeed, if we subscribe to the idea that energy-consuming behaviours are often guided by habits, and that deeply ingrained habits can become counter-intentional (Verplanken and Faes, 1999), it then follows that people may often display 'locked-in' practices in their daily energy consumption behaviour.

The next step is thus to assess the role of habits in influencing energy consumption behaviours. To start with, it seems obvious that behaviours such as switching off the lights or turning off appliances (i.e. 'curtailment behaviours' in the sense of Gardner and Stern, 2002) meet the three conditions identified by Jackson (2005, p. 64) for the balance of the decision-making process to swing away from cognitive effort and towards automaticity: low degree of involvement, low perceived complexity, and high degree of constraint.[16] One other important element that characterizes domestic energy consumption is that it is not visible (Abrahamse et al., 2005; Jackson, 2005). This implies that people do not consider the remote environmental impacts of their actions when performing energy-related behaviours. This obviously facilitates the retention of unsustainable habits in this area (Martiskaïnen, 2008, p. 77).

All together, this suggests that everyday energy-related behaviours do not require much intentional effort to be set in motion, such as it has been shown to be the case of, for example, food consumption in adolescents (Kremers et al., 2007). This is in line with a recent empirical analysis, where energy use – along with nutrition and mobility – are seen as 'forms of behaviour that are hardly reflected upon in everyday life' (Schäfer and Bamberg, 2008, p. 213). This is also corroborated by a review of studies on domestic energy consumption where one of the lessons learnt is that the importance of habits can 'prevent that (pro-environmental) behaviour from happening' and make a person 'act opposite to his or her intentions without even realising it' (Martiskaïnen, 2008, p. 87).

3.4. Contribution of the evolutionary view

As mentioned in a previous paper (Maréchal, 2007), this evolutionary perspective of economics is of great importance for energy- and climate-related issues in at least three different ways. First, it has been shown by Grubler (1998) that the past two centuries could be viewed as the succession of essentially three socio-technical systems (STS), all based on a source of energy. In line with this approach, some analysts argue that we are currently locked into a carbon-based STS as our economies strongly rely on the use of exhaustible fossil fuels (Unruh, 2000; Arentsen et al., 2002).

Second, since the emergence of a given STS is historically contingent, and thus not only governed by optimality, it may be that it is based on an inferior design of technology (David, 1985).

Third, as Shove (2004) observed: technologies are embedded in a strongly influential social context of institutions which shapes consumption while also being shaped by technological constraints. Given that a 'structure is always both enabling and constraining' (Giddens, 1984, p. 169), choices in energy consumption are strongly influenced by the existing carbon-based STS through wider forces such as norms, media, technical designs, etc. (Shove et al., 2008; Strengers, 2008). To be functional, people's habits have to be 'accordant' with prevailing socio-technical forces which shape consumers' choices towards more energy-consuming ways of life. This can be illustrated by the increase in average internal temperatures in UK houses from 13.8°C in 1970 to 18.2°C in 2004,[17] while the average number of electric appliances increased from 17 to 47 over the same time period (Healy, 2008; Martiskaïnen, 2008). In addition, while choices in energy consumption are being strongly influenced by the existing STS, they, in turn, contribute to reinforcing and maintaining the incumbent STS.

The evolutionary framework adopted in this article is thus crucial because it builds on the idea that individuals and institutions 'mutually constitute and condition each other' (Hodgson, 1997, 404).[18] This mutual constitutiveness renders habits an additional factor of technological stability. In turn, this provides a two-fold complementary explanation for the existence of the 'efficiency paradox' beyond the common economic ones.

4. Implications for policy-making

Even though the added value of complementing economic analyses of climate change with an evolutionary perspective has been clearly shown in the previous sections, Nelson and Winter (1982) remind us that the 'ability of a theory to illuminate policy issues ought to be a principal criterion by which to judge its merit'. This is why, in this section, we provide some insights into the implications for policy-making that arise from adopting an evolutionary approach.

We can summarize the contributions of evolutionary economics to the issue of climate change by pointing to both its departure from the perfect rationality hypothesis and its shift of focus towards a better understanding of economic dynamics. Such a framework allows us to depict the presence of two sources of inertia (i.e. at the level of individuals and at the level of socio-technical systems) that mutually reinforce each other. This is in line with a recent empirical analysis in the field of energy consumption in Denmark which shows that there are both 'similarity and collectivity' as well as 'variety and individuality' in behaviours (Gram-Hanssen, 2008, p. 14).

Given this context, policies aiming at reducing energy consumption and GHG emissions would thus have to deal with both sources of resistance to change. This means not only shifting the incumbent carbon-based STS so that starts to shape decisions towards the desired direction (i.e. a low-carbon economy) but also deconstructing the habits that this same STS has forged with time.

Recommendation 1: The maintenance of solution diversity is important for allowing climate-friendly technologies to emerge

Unlocking from a desirable trajectory that is no longer desirable is not a task that can easily be undertaken, since it is difficult to identify the solution that would yield the best outcome. Collective learning in the field of policy-making is largely indeterminate and policy-makers may be tempted to skip the learning phase if this leads to policies that meet their aspiration 'even if the policy would be inferior from the point of view of an omniscient observer' (Schnellenbach, 2005, p. 115). Wisdom would thus require governments to delay their commitment to an inextricable future and leave a diverse range of technological options open (Berkhout, 2002, p. 3).[19]

If their ability to foresee the future is obviously limited, policy-makers should then learn about the evolutionary processes at play. In their thorough review of Dutch environmental policy, van den Bergh et al. (2007) provided a good illustration of the inherent difficulty of applying evolutionary principles. For instance, 'diversity is acknowledged in policy documents, but in practice this applies mainly to diversity in technologies and much less to diversity in companies, products and strategies' (van den Bergh et al., 2007, p. 87). In fact, most of the evolutionary insights that appear to be conflicting with the general focus on efficiency are often neglected by policy-makers.

What is needed in the case of climate policy is a technological succession (Windrum and Birchenhall, 2005), which is considered as a necessary condition for attaining a low-carbon society (Koehler et al., 2006, p. 18). In other words, there needs to be a transition from the incumbent socio-technical system to a more climate-friendly configuration. Bearing in mind the aforementioned interrelations between demand, technology and society, 'long-term technology policy should take account of the socio-cultural contexts in which technologies fit' as claimed by Wilhite (2007, p. 29). Policy-makers should thus learn about those interactions and promote the type of measures that have been proven successful in overcoming lock-in situations (Mulder et al., 1999; Windrum, 1999).

One inevitable consequence of looking at technical change through an evolutionary framework is that transitions will typically involve a multi-level dynamic of complex interactions and feedbacks in a path-dependent manner. This clearly means that the outcome will be of an emergent (i.e. rather than planned and structured), uncertain and complex nature (Raven, 2007). Accordingly, policy-makers should refrain from 'picking winners' and instead create conditions under which the evolutionary process of economic change would lead to the desired outcome (i.e. climate protection in this case).

There are two broad strategies that are commonly identified in the literature as being capable of triggering transitions: niche[20] accumulation and hybridization (Raven, 2007, p. 2392), with the former starting from a radically distinct field, while the latter builds on the existing regime.[21] Accordingly, both strategies display advantages and drawbacks that are related to their respective closeness to the incumbent regime. This may explain why, in practice, it seems that successful transitions often involve a mix of both strategies, as illustrated with the example of the gas-turbine which shows that both strategies were required to overcome the lock-in of the incumbent steam power plant (Islas, 1997). This view is confirmed in an analysis of distributed generation of electricity, where it is noted that 'some elements of the old regime were vigorously rejected, while others were carried along into the new regime' (van der Vleuten and Raven, 2006, p. 3747).

Recommendation 2: Motivate consumers with other measures than the usual incentives to shift from the existing carbon-based socio-technological system

In line with the aforementioned insight of the evolutionary perspective that highlights the presence of habits in energy consumption, a necessary change would be for decision-makers in the energy and climate field to stop focusing only on technology and innovation and take into account the interrelations with the demand-side and society. The incremental improvements brought to a nascent technological option do not only come from 'producers of new knowledge but also from users' (Schot and Geels, 2007, p. 607).

Acknowledging the role of habits, an innovative policy instrument is the Brussels Energy Challenge, which sees citizens committing themselves to implementing at least one of the fifteen energy-saving actions proposed by the regional authorities. As developed in more detail by Maréchal (2009), there are various strategies that can contribute to changing unsustainable habits in the field of energy consumption. Among those different options, making the alternative behaviour more rewarding seems to provide an interesting point on which to base sustainable energy measures. This is confirmed by the answers provided by respondents who took part in the Brussels Energy Challenge, as it is the very notion of 'challenge' that is considered to be the most 'interesting' aspect of the proposed policy.[22] In fact, as mentioned by Matthies et al. (2006, p. 94), commitment strategies (i.e. as with the Brussels Energy Challenge) enhance 'self-satisfaction as a result of acting in accordance with personal values', and therefore increases 'the cost of not acting'.

The rational choice model has paved the way for the current state of policy-making where decision-makers 'obsessively invoke 'incentives' as the panacea for any given social problem' (Hayes, 2007). But the aforementioned locked-in practices in energy consumption in the form of individual habits or organizational routines tend to reduce the effectiveness of such 'antecedent measures' (Abrahamse et al., 2005; Verplanken and Wood, 2006; Martiskaïnen, 2007). When habits are deeply ingrained, they often hinder individuals' attempts to perform a new behaviour even when they formulate a firm intention to do so. This can also be the case for collective routines (Cohen, 2006, p. 388). In addition, routines have a narrative role which is especially pronounced with those routines people pretend to follow. This essential element is referred to as the 'ostensive' dimension of routines and has been discussed by Feldman (2000). Policy-makers should bear in mind the potential discrepancy which may exist between those 'ostensive routines' and 'performative routines' (i.e. routines in operation and actually used). This rather frequent gap between intention and action should not be ignored when policy-makers try to promote new types of behaviour.[23]

Such psychologically rooted non-economic barriers are thus an important part of the explanation. They would require a wider range of policies to be implemented if decision-makers wish to reverse the trend of consumers not always adopting profitable energy-saving regardless of their strong intention to do so. In short, even though economic incentives may have some influence, they are far from being the unique relevant factor. Strategies that interfere with the 'intrinsic motivation' of individuals may sometimes be rejected by the population, which makes it necessary to turn to alternative ways (Gagné and Deci, 2005). As has been shown by Frey (1999) about environmental goals, 'intrinsic motivation' cannot be easily regulated. In some cases, extrinsic motivation (e.g. produced by incentives) may undermine the existing motivation and create a 'crowding-out effect', as illustrated by the famous example of blood donors in Switzerland[24] (see also Gowdy, 2008, on this point).

This does not mean that policy-makers should totally give up the usual tools, such as economic incentives, but they have to learn in which contexts they may turn out to be counter-productive by reducing existing motivation. Furthermore, the aforementioned role played by habits and routines may also need to complement traditional measures in order to enhance their effectiveness. In accordance with empirical studies highlighting the importance of context stability for habit formation (Wood et al., 2005; Danner et al., 2008), McMakin et al. (2002, p. 851) claim that 'intervention efforts should explicitly include the characteristics of the targeted living situation and its residents'. This is the essence of the 'downstream-plus-context-change interventions' proposed by Verplanken and Wood (2006, p. 96). The increased effectiveness of linking traditional measures to sensitive life events or changes of context has been validated empirically in several studies (Satoshi and Gärling, 2003; Bamberg, 2006, 2007; Verplanken et al., 2008).

More generally, there is no 'one size fits all' measure, and effective interventions should thus be tailored to the characteristics of the targeted group (e.g. norms and motives, consumption profiles, etc.). The variability of habits within a similar carbon-based STS shaping individuals towards energy-consuming behaviours is probably one reason why 'many studies have shown that a combination of strategies is generally more effective than applying one single strategy' (Abrahamse et al., 2005, p. 282).

Recommendation 3: Target 'lead users' and pave the way for a transition towards a low-carbon STS

If different people tend to display different habits (and different propensities to rely on habits) and if the interplay with users is essential for a nascent technology to mature, it is then straightforward to look for those individuals, called 'lead users', who are most likely to use new technologies (i.e. those that have the habit of looking for novelty). The idea is thus to build on the same interplay between individuals and socio-technical influences described in the previous section in order to trigger a positive feedback process towards a low-carbon STS. As shown by Buenstorf and Cordes (2008), social groups play an important role in introducing change, given the general tendency to imitate prestigious individuals. For example, Hollywood stars have contributed to the promotion of new behaviours in favour of small 'green cars', which has had a huge impact on those 'traditional' automobile companies that were unable to adapt to the new consumption patterns. However, although the importance of social learning may temporarily overcome the strong 'hedonistic' bias that favours unsustainable behaviours, the permanent trade-off between these two contradicting forces suggests that recently induced 'green behaviours' can perhaps not be sustained in the face of new knowledge (Buenstorf and Cordes, 2008). The interplay between habits and socio-technical accounts is thus essential to grasp, because of the risk of seeing climate-friendly behaviours newly adopted by individuals being quickly 'crowded out' by wider forces.

Nonetheless, policy-makers should seriously take into account the role of those groups which create favourable conditions for the emergence of new niches and may prepare the ground for the transition between different STS. In this context, policy-makers should create conditions that favour the emergence of those 'lead users'. Indeed, these highly intrinsically motivated individuals may play a decisive role in technological development, as has been seen through the creation of open source software (von Krogh and von Hippel, 2006). In addition, public authorities can also play their part in modifying intrinsic and extrinsic motivation through the development of large and visible public investments that may instil new values inside social groups. The example of the city of Perpignan is illustrative of the importance of creating significant 'small events'. By massively investing in solar energy for the St Charles fruit and vegetable market, a highly visible and well-known institution, municipal authorities have played a critical role in promoting 'green' technology (Cros, 2008). This small decision was decisive, as it triggered an increased adoption by households through generating a kind of 'bandwagon effect' for the diffusion of solar technology in the city.

5. Conclusions

Our analysis has shown that adopting an evolutionary perspective could provide decision-makers with crucial complementary insights for dealing with energy- and climate-related issues. For instance, the lock-in process makes it unlikely that traditional cost-efficient measures aimed at internalizing external costs will be sufficient to bring about the required radical change in the field of energy, because they fail to address structural barriers (del Rio and Unruh, 2007, p. 1511). Furthermore, one consequence of the existence of habits (which are clearly at play in energy consumption) is that pricing instruments alone will not be sufficient to trigger change at the level of agents (van den Bergh et al., 2006). Micro-level interventions are thus needed as much as macro-level ones since, due to the potential rebound effect arising from unchanged energy-consuming habits, 'an exogenous increase in energy efficiency may not lead to lower energy consumption' (Brännlund et al., 2007, p. 15).

Accordingly, climate policies should instead create conditions enabling the use of the cumulative and self-reinforcing character of economic change highlighted by evolutionary analyses (Mulder et al., 1999) and take into account the current lock-in of our economies in a carbon-based STS. Similarly to the idea that disturbing the contextual forces which contribute to maintaining 'counterintentional habits' seems an inevitable strategy for changing them (Maréchal, 2009), destabilizing the currently prevailing carbon-based STS is a necessary first step in initiating the transition towards a low-carbon economy.

Acknowledging this, and building on the insights from the evolutionary approach, policy-makers should go beyond their traditional role of simply financing technology, and should support both social and physical technologies. As confirmed in an analysis of the German electricity sector, circularity and cumulative causation (i.e. the building blocks of the evolutionary framework) are essential features in such transition processes (Jacobsson and Lauber, 2006, p. 272). In line with the claim that we 'should not confuse 'optimal' with 'what survives'' (Schot and Geels, 2007, p. 607), policies could thus aim at influencing the selection environment such that 'only the greenest technologies will survive' (van den Bergh et al., 2006, p. 70).

Notes

1. We use the word 'mainstream' ('modern', 'traditional' or 'orthodox' could also be used) to avoid the problems arising from the somewhat ambiguous use of the term 'neoclassical', as shown in Colander (2000). By mainstream economics, we refer to the Walrasian model of welfare economics which can be defined as the theoretical synthesis of the Marshallian approach with marginal production theory and the rigorous precision of mechanical mathematics.
2. The range of models used in the Special Issue of the *Energy Journal* on the costs of the Kyoto Protocol (Weyant, 1999) provides a clear example of the omnipresence of CGE models in economic analyses of the climate issue.
3. The concept of 'bounded rationality' refers to the cognitive boundaries that prevent people from seeing, seeking, using and sharing relevant accessible and perceivable information when making decisions. Rationality is bounded, since individuals face limits both in formulating and solving problems and in processing information.
4. Note that this theory is somewhat at odds with the abundant empirical evidence of behavioural inconsistencies such as loss aversion or hyperbolic discounting. Beyond these inconsistencies, Quiggin (2008, p. 199) also adds that markets 'do not work in the smooth and frictionless' way assumed in standard models.
5. One example of misplaced concreteness is the battle over the figures contained in the Stern Review – notably regarding the appropriate discount rate to be used – which has given rise to extensive debate in the literature (see, for instance, Tol and Yohe, 2006; Nordhaus, 2007; Barker, 2008). The focus could have been placed instead on the meaning of the proposed measures and the costs of adaptation of socio-economic systems to a changing climate.
6. For a good overview of that debate, see IPCC (1996, chapters 8 and 9) and the Special Issue of *Energy Policy* (Huntington et al. 1994).
7. Interestingly, Barker (2008, p. 175) notes that it may also be the case in the debate around the appropriateness of cost-benefit analyses (CBA) in the field of climate change, judging by the responses of traditional economists to the Stern Review.
8. See Sutherland (1991) and Howarth and Andersson (1993), who explain the 'efficiency paradox' through the existence of hidden costs – mostly transaction costs.
9. See the limits of, for instance, market forces in de Almeida (1998); of energy labels in Gram-Hanssen et al. (2007); and of price signals in Meier and Eide (2007).
10. Note that, as mentioned by Schleich and Gruber (2008), 'the categorization of barriers is contested in the literature in the sense that different authors use different typologies'. For instance, Kounetas and Tsekouras (2008, p. 2519) present four distinct categories of factors explaining the efficiency paradox. One of these refers to non-economic factors (e.g. environmental regulation, labels, etc.) but that are not of a psychological nature.
11. However, routines are not reducible to the mere sum of individual habits. As Hodgson (2007, p. 111) clearly puts it '[r]outines are organizational meta-habits, existing on a substrate of habituated individuals in a social structure'.
12. Although it was not apprehended in the same manner as in this article, the important role of inertia in climate policy has already been acknowledged by Grubb et al. (1995).

13. It should be noted that a 'system' is a network of elements, whereas a 'regime' is a network of people. Socio-technical regimes serve to maintain and stabilize socio-technical systems (see Geels and Kemp, 2007).
14. In line with the concept of 'path-dependence' which refers to the fact that technological systems follow specific trajectories that it is difficult and costly to change (Arthur, 1983; David, 1985). As shown by Arthur (1989), these trajectories depend on historical circumstances, timing and strategy as much as optimality (i.e. the main focus of mainstream economics). As defined by Puffert (2002, p. 282), a path-dependent process is 'one in which specific contingent events – and not just fundamental determinative factors like technology preferences, factor endowments and institutions – have a persistent effect on the subsequent course of allocation'.
15. Habits can be characterized as a context-dependent form of acquired automaticity. However, this automaticity is somewhat limited (i.e. it is only a 'predisposition') by a required functionality or correspondence with objectives.
16. This high degree of constraint arise from the feelings of time pressure and information overload that characterize today's society, as explained by Lindbladh and Lyttkens (2002).
17. Even though the range of what people report to be a comfortable temperature is wide, indoor climate is converging (Shove, 2004; Shove et al., 2008).
18. To put it differently, 'habits are the constitutive material of institutions', while the presence of institutions ensures that 'accordant habits are further developed and reinforced among the population' (Hodgson, 2007, p. 107).
19. For instance, in the 'Battle of the motors', US engineers were able to switch from electric to gas-powered vehicles because they 'did not put all their eggs in one basket, nor were they irrevocably committed to any particular technology' (Foreman-Peck, 1996, p. 9).
20. A niche is a limited space where new technologies can mature. When there is a protection (whether public or not), a niche is said to be technological. If not, it is called a market niche (Mulder et al., 1999, p. 11). For instance, the Internet was developed within a technological niche, whereas railways grew within a market niche (Windrum and Birchenhall, 2005, p. 125).
21. For example, as far as car fuel is concerned, agro-fuel is a form of hybridization, whereas the development of fuel cells is a niche.
22. It has a score of 9.06 on a scale ranging from 1 to 10 anchored by 'not at all interesting' to 'very interesting'. For instance, 'the feeling of acting individually to fight against a global issue' has a score of 8.30, whereas the score of 'individual follow-up' is only 5.60. The complete results can be found in the June 2007 report on www.defi-energie.be (in French).
23. For instance, as far as green products are concerned, when consumers actually purchase a car, they do not always put in practice their intentions (Meyer et al., 2006; Englert et al., 2009).
24. The number of blood donors decreased after the introduction of a reward, as it appeared to conflict with the values of voluntary donors (for a recent debate on the 'crowding-out' effect, see Mellström and Johannesson, 2008).

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